Late Gadolinium Enhancement for Left Ventricular Lead Guidance in Cardiac Resynchronization Therapy: Comparison of 3D Free-breathing IR-FLASH vs 2D Breath-hold Phase-Sensitive IR

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Purpose

Cardiac Resynchronization Therapy (CRT) is a treatment for patients with heart failure and evidence of ventricular dyssynchrony that uses a biventricular pacemaker to create synchronous ventricular contraction. Optimal patient response to the therapy has been associated with left ventricular (LV) lead implantation in the latest contracting region of the myocardium that is not predominantly myocardial scar. However, transvenous implantation through the coronary sinus limits lead implantation locations to regions that can be accessed by the coronary veins. Thus, optimal implantation planning necessitates co-registered myocardial scar and coronary venous images.

MRI can visualize the coronary veins by using 3D, contrast-enhanced, free-breathing FLASH and can visualize myocardial scar distribution by using the current clinical standard, a 2D, late gadolinium enhancement (LGE), breath-held, phase-sensitive inversion recovery (PSIR). Since the site of latest contraction is frequently at or near a region that is predominantly myocardial scar, an adjacent segment of myocardium is often a desirable site for LV lead implantation [1]. However, the different voxel sizes and respiratory positions complicate co-registration between the two sequences and subsequently complicate accurate projection of angiography and scar data onto an AHA 17-segment bullseye that can be used for LV lead planning. A 3D IR-prepared FLASH sequence can also be used for LGE [2]. The purpose of this study was to evaluate the potential of 3D, LGE, free-breathing, IR-prepared FLASH to quantify scar volume, scar transmurality, and scar distribution on the AHA 17-segment bullseye compared to the clinical standard, 2D LGE-PSIR images.

Methods

4 patients with known previous myocardial infarction received a cardiac MR on a 1.5T clinical scanner (Avanto, Siemens Healthcare, Erlangen, Germany). A gadolinium-based contrast agent (0.15 mmol/kg MultiHance) was injected at 0.3 mL/s and imaging started 45 seconds after contrast injection. A 3D, navigator-gated and ECG-gated IR FLASH sequence was acquired in the transverse orientation to cover the left ventricle for angiography images. A look-locker inversion recovery was acquired 10 minutes after contrast to determine the proper inversion recovery time, and multiple 2D LGE-PSIR short-axis images were acquired for complete left ventricle coverage. Sequence parameters were: TR/TE/FA = 700 ms/2.82 ms/25° with IR = 200 ms and resolution 1.8 x 1.8 x 8 mm^3. The 3D sequence was re-acquired to produce 3D LGE -FLASH images. Sequence parameters were: TR/TE/FA = 3.3 ms/1.44 ms /15° with an acceleration factor of 2. 52 partitions were acquired and interpolated to104 slices with a final pixel size of 0.76 x 0.76 x 0.75 mm^3.

The 3D LGE-FLASH images were reformatted to the short-axis orientation and the myocardium was segmented on both the 2D LGE-PSIR and 3D LGE-FLASH images. Pixels with intensity greater than the mean plus 2 standard deviations of healthy myocardial intensity were determined to be scar and the total scar volume for each patient was calculated. 360 radial spokes were drawn from the centroid of the endocardial border to the edge of the epicardial border to calculate scar transmurality across the myocardium for all slices and create the 17-segment AHA bullseye. 3D LGE-FLASH images were aligned with 2D LGE-PSIR images to compare the scar transmurality of the radial spokes. Transmurality of the radial spokes was categorized into < 50% transmural scar (viable myocardium) or > 50% transmural scar (non-viable myocardium) to create a 2x2 contingency table for viability at each spoke, using the 2D LGE-PSIR as the reference standard. 3D LGE-FLASH images were manually co-registered to the 3D angiography images in the slice direction and automatically in-plane by performing a cross-correlation. The coronary venous anatomy was segmented to produce a point cloud from the 3D angiography images then transferred to the bullseye by finding the angle of the radial spoke that intersected each coronary vein point on the corresponding short-axis image.

Results

The average scar volume across the patients was 20.8 ± 4.7 cm^3 as measured by the 2D LGE-PSIR was 16.2 ± 6.7 cm^3 as measured by the 3D LGE-FLASH. The difference between these two measurements was not statistically significant by a paired t-test ($p = 0.25$). A comparison of >50% scar transmurality from 3D LGE-FLASH radial spokes (using 2D LGE-PSIR radial spokes as the standard) yielded 71% sensitivity and 92% specificity for 3D LGE-FLASH in differentiating viable myocardium from transmural myocardial scar. Figure 1 shows a comparison of the AHA 17-segment bullseye between the 2D LGE-PSIR images and the 3D LGE-FLASH images with the co-registered coronary venous anatomy. The extent of scar as displayed by the 2D LGE-PSIR bullseye shows qualitative similarities when compared to the 3D LGE-FLASH bullseye. However, several anterior locations on the 2D LGE-PSIR bullseye show fully transmural scar while the corresponding segments on the 3D LGE-FLASH bullseye were not fully transmural.

		LGE	
		> 50%	< 50%
PSIR	> 50%	18.4%	7.6%
	< 50%	6.1%	67.8%

Table 1: Comparison of the myocardial viability from radial spokes drawn across the myocardium. < 50% represents viable myocardium while > 50% represents scarred myocardium.

Discussion

The difference between the 3D LGE-FLASH and 2D LGE-PSIR for the total volume of scar difference was not significant, suggesting that the 3D LGE-FLASH images are equivalent to the clinical gold standard, 2D LGE-PSIR. The slightly lower values for scar volume could be due to 2D LGE-PSIR overestimating the scar volume due to partial volume effects, which is supported by the slightly lower 71% sensitivity of LGE-FLASH in identifying a transmural segment of myocardium. It is important to note that the total acquisition time of all the 2D LGE-PSIR short-axis slices (10–15 slices) took on average 8.0 ± 0.7 minutes. Our previous experience has shown that a 3D, whole-heart free-breathing FLASH sequence required approximately 9.8 ± 2.5 minutes for acquisition [2]. While this takes slightly longer than the 2D LGE-PSIR images, the ease of co-registration, lack of breath-holding, and higher resolution allows for more optimal LV lead placement planning.

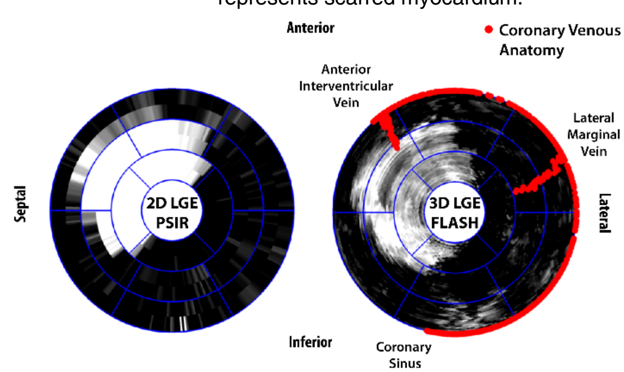

Figure 1: 2D LGE PSIR and 3D LGE-FLASH 17-segment AHA bullseye. Red dots represent the coronary vein anatomy.

Conclusion

3D LGE-FLASH is capable of quantifying scar volume with accuracy equivalent to the current gold standard, 2D-PSIR. The resulting higher resolution images and ease in transferring coronary anatomy and scar location to the bullseye map may help lead to more optimal LV placement for CRT.

References

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